Prediction and Modal Analysis of Supersonic Jet Noise From Complex Nozzles in an Integrated Simulation Environment, Phase I

Completed Technology Project (2018 - 2019)

Project Introduction

Our long-term vision is to seamlessly integrate resolvent operator-based spectral analysis into Cascade's high-fidelity large eddy simulation (LES) environment, for accurate prediction and efficient modeling of supersonic jet noise from complex nozzles. Resolvent analysis is a frequency-domain technique that can identify resonance phenomena such as jet screech and other tonal acoustic effects, predict the large-scale coherent structures that are the main source of aft angle jet noise, and that provides, at the same time, sensitivity maps that can be used for optimal sensor or actuator placement for noise control. Cascade's LES framework features a novel mesh generation paradigm based on the computation of Voronoi diagrams, which allows for the generation of high-quality, body-fitted, conformal meshes and the use of low-dissipation numerical methods required for high fidelity large eddy simulations of multi-scale turbulent flows in complex geometries. We project that the combination of the Voronoi-based LES and resolvent analysis can be successfully commercialized by assuming a role similar to that of modal analysis in solid mechanics. In Phase I, we propose the case of a heated supersonic over-expanded turbulent jet issuing from a circular convergent-divergent nozzle as a testbed for both Cascade's Voronoi-based LES framework and a resolvent analysis tool provided by Caltech as a subcontractor. The first task is to implement and validate shock-capturing capabilities into both the resolvent tool and LES compressible flow solver "Charles". Armed with the large-eddy simulation data, The second task is to conducte a detailed resolvent analysis of the over-expanded turbulent jet, with special emphasis on broadband aft angle and tonal shock-induced noise. In parallel, the final task is to perform a proof-of-concept simulation for an airframe-integrated nozzle, as a demonstration of the meshing and prediction capabilities for complex geometries.

Anticipated Benefits

The supersonic over-expanded turbulent jet test case proposed as a testbed for our numerical method mimics the take-off operation conditions of supersonic commercial aircraft such as NASA's Quiet Supersonic Transport design. Other technologies that potentially benefit from resonance mechanism identification include the chemical thrusters and rocket boosters used by NASA's Orion spacecraft and Space Launch System.

Jet noise and flow-induced vibrations affect the surrounding structures and flight deck crew on aircraft carriers. Our envisioned simulation and analysis tools are therefore ideally suited to guide the aeroacoustical design and optimization of Naval aviation programs. Similarly, passive noise mitigation measures used in the commercial aviation sector such as chevrons can benefit from our developments.

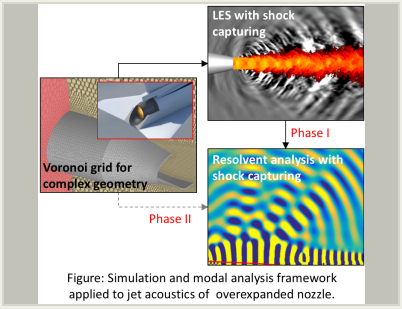

Figure: Simulation and modal analysis framework applied to jet acoustics of overexpanded nozzle.

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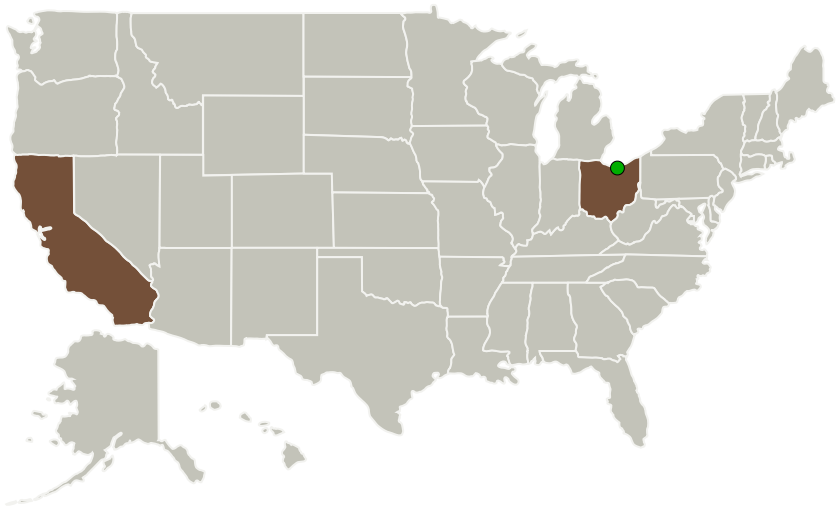
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
CASCADE Technologies, Inc.	Lead Organization	Industry	Palo Alto, California
Glenn Research Center(GRC)	Supporting Organization	NASA Center	Cleveland, Ohio

Primary U.S. Work Locations	
California	Ohio

Project Transitions

July 2018: Project Start

February 2019: Closed out

Closeout Documentation:

- Final Summary Chart*(https://techport.nasa.gov/file/137882)*

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

CASCADE Technologies, Inc.

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

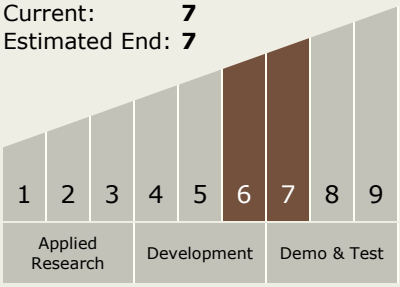
Carlos Torrez

Principal Investigator:

Guillaume A Bres

Technology Maturity (TRL)

Start: **6**
Current: **7**
Estimated End: **7**



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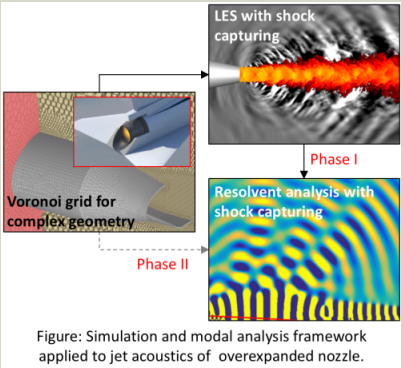
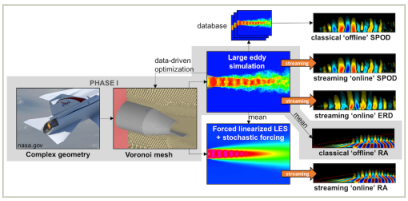
Images



Briefing Chart Image
Prediction and Modal Analysis of Supersonic Jet Noise From Complex Nozzles in an Integrated Simulation Environment, Phase I
(https://techport.nasa.gov/image/129014)



Final Summary Chart Image
Prediction and Modal Analysis of Supersonic Jet Noise From Complex Nozzles in an Integrated Simulation Environment, Phase I
(https://techport.nasa.gov/image/126923)

Technology Areas

Primary:

- TX15 Flight Vehicle Systems
  - TX15.1 Aerosciences
    - TX15.1.4 Aeroacoustics

Target Destination

Earth